

**Goddard Space Flight Center**

**18th Global Grid Forum**

**Transforming Space Missions Into Service Oriented Architectures**

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September 12, 2006

**Large Incidents - August 22, 2003**

**Terra (MODIS)**

**Aqua (MODIS)**

**MODIS Active Fire Map**

**Sensor Planning Services (SPS)**

**EO-1 (ALI & Hyperion)**

**Goddard Space Flight Center**

**Vision: Sensor Web Enablement via a Service Oriented Architecture (SOA)**

**Scientists**

**Land Remote Sensing Observation Data**

**Earth Weather Data**

**Space Weather Data**

**Sensor Planning Services (SPS)**

**Sensor Alert Services (SAS)**

**Sensor Registry Services (SRS)**

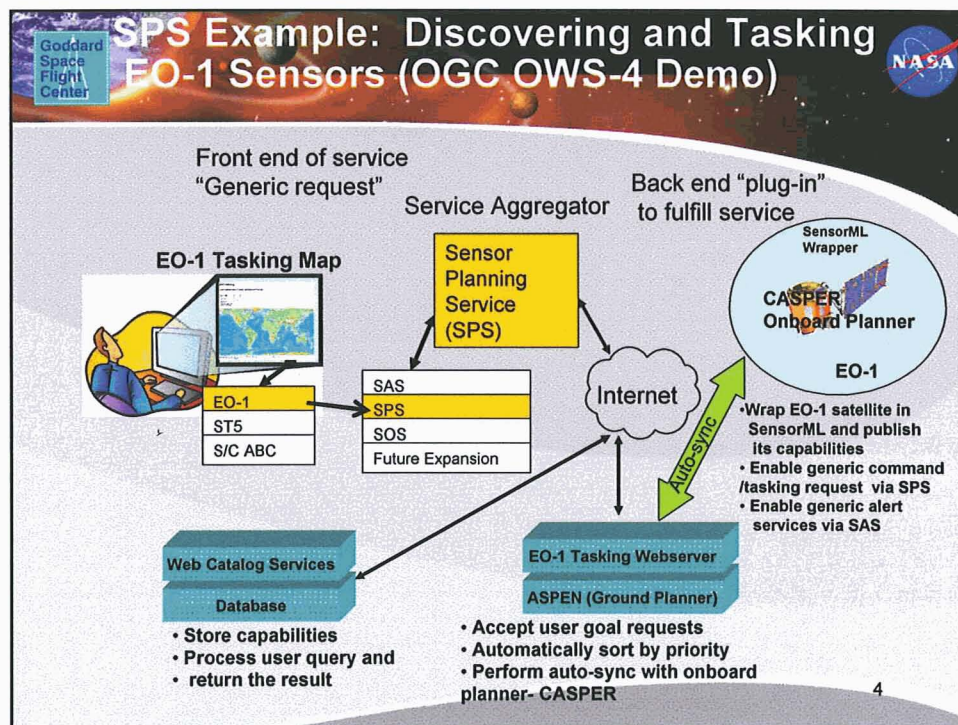
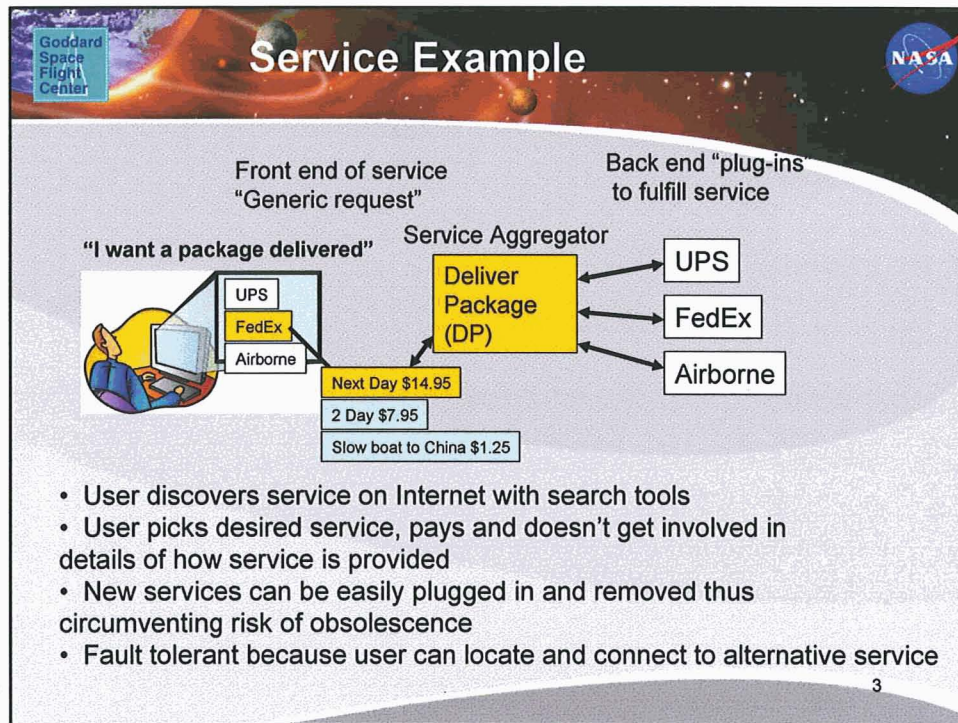
**Sensor Observation Services (SOS)**

**Work Flow Chaining Services (WfCS)**


- Abstract data from process of obtaining data via services above
- Access sensors and data via Internet and use services similarly to how "Google Earth" is used
- User chains multiple services from various sensors and data service providers together as needed
- Built on top of GMSEC and cFE

2










## SPS Example: Discovering and Tasking EO-1 Sensors (OGC OWS-4 Demo)



### EO1 GeoBlink

Sensor Web Enabled (SWE) Data Node  
Welcome: Dan Mandl - Permissions: blink, all  
settings connections Logout

**Tiva [EDC/N] 5654f**

Posted in: Web Master - Data - Operations - 2006-08-22

A new EO1 hypersion image has been generated for Tiva [EDC/N] 5654f on Tue Aug 22 19:46:28 UTC 2006 Links at ASE - or EO1 Home Site

Latitude: -16.6322  
Longitude: -151.54

**Tiva [EDC/N] 5654f**

Posted in: Web Master - Data - Operations - 2006-08-22


A new EO1 all image has been generated for Tiva [EDC/N] 5654f on Tue Aug 22 19:46:28 UTC 2006 Links at ASE - or EO1 Home Site

Latitude: -16.6322  
Longitude: -151.54

**EO1 Tasking**

Use crosshair tool to select lat/long from the map

Daylight: Day  
Latitude:   
Longitude:   
[Get From EDC/N](#)




EO1 Feasibilities Options

Things you can do:  
[Back to Tasking](#) [My Tasks](#)


Your EO1 Day tasking in all 800 x 600 options are:

Day: 244 UTC: 2006-08-21 10:05:00 SDA: 29.52 Type: WEST Cent: 51328.13 (near weather)
Day: 245 UTC: 2006-08-21 10:05:00 SDA: 34.86 Type: EAST Cent: 51439.78 (near weather)
Day: 246 UTC: 2006-08-21 10:05:00 SDA: 29.74 Type: WEST Cent: 51279.43 (near weather)
Day: 251 UTC: 2006-08-21 10:05:00 SDA: 33.16 Type: EAST Cent: 51974.30 (near weather)
Day: 254 UTC: 2006-08-21 10:07:00 SDA: 32.21 Type: WEST Cent: 51516.31 (near weather)
Day: 258 UTC: 2006-08-21 10:09:00 SDA: 26.79 Type: EAST Cent: 51516.31 (near weather)
Day: 260 UTC: 2006-08-21 10:09:00 SDA: 26.79 Type: WEST Cent: 51516.31 (near weather)
Day: 361 UTC: 2006-08-21 10:09:00 SDA: 26.79 Type: EAST Cent: 51516.31 (near weather)
Day: 364 UTC: 2006-08-21 10:09:00 SDA: 26.79 Type: WEST Cent: 51516.31 (near weather)
Day: 365 UTC: 2006-08-21 10:09:00 SDA: 26.79 Type: EAST Cent: 51516.31 (near weather)
Day: 366 UTC: 2006-08-21 10:09:00 SDA: 26.79 Type: WEST Cent: 51516.31 (near weather)

[Return to main page](#)



## SPS Example Using ST5 Built on Top of GMSEC



Front end of service  
"Generic request"

**Sensor Types**

Land Remote  
Earth Weather  
Space Weather

**ST5**

S/C XYZ  
S/C ABC

Service Aggregator

**Sensor Planning Service (SPS)**

**Power**  
SSR  
RF Link  
Future Expansion

Back end "plug-in" to fulfill service

**ST5 Planner**

**ST5 T&C**

**SimulinkST5**

Matlab / Simulink

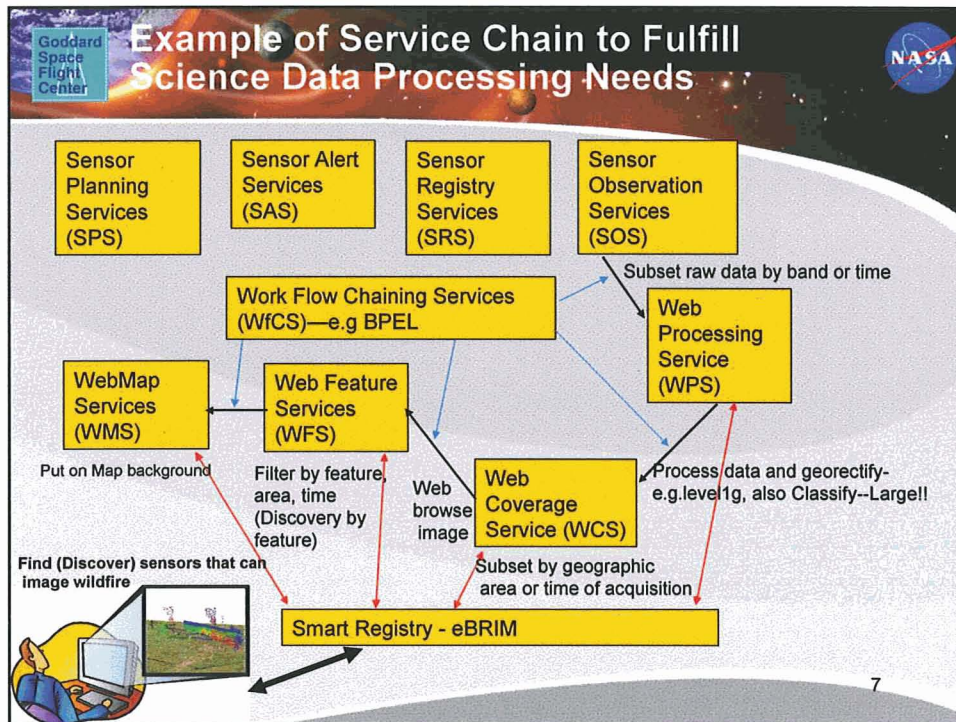
Future SSR Power RF

**GMSEC Bus**

Interoperable Message Bus

- Validated new "back-end" predictive models which predicted problems for selected subsystems (SSR, RF Link, Power) and then autonomously initiated corrective actions through planning system before problem occurred
  - Unique innovation--Models self-update over time using real-time telemetry (e.g. as solar array degrades, charge current for battery changes over time, therefore model of state of battery has to change)
- Used GSFC Mission Services Evolution Center (GMSEC) message bus to enable communications between support components

6

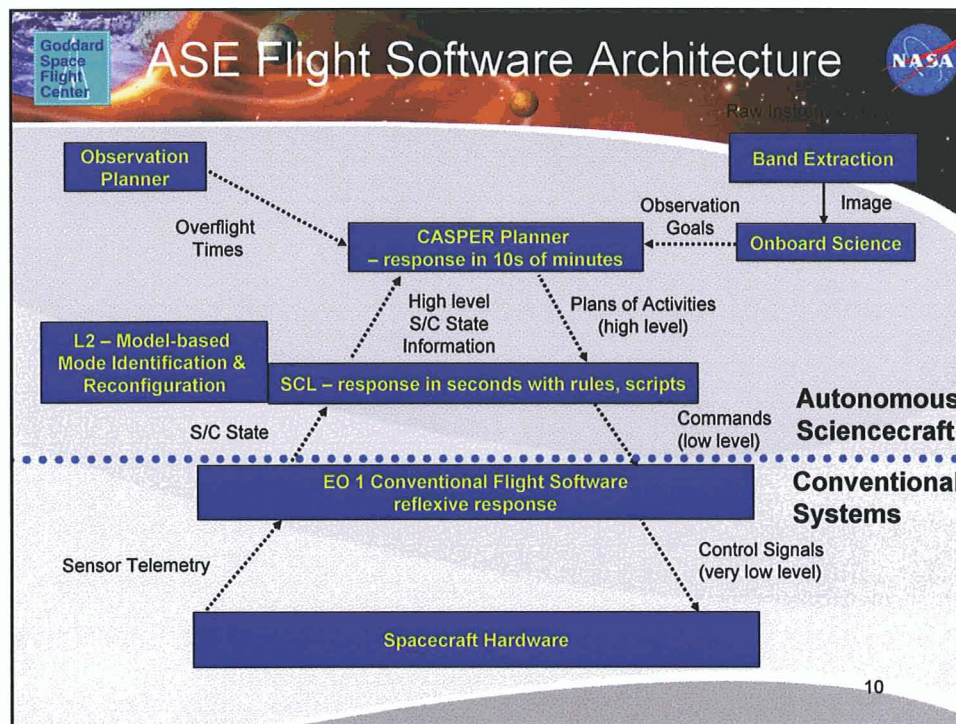
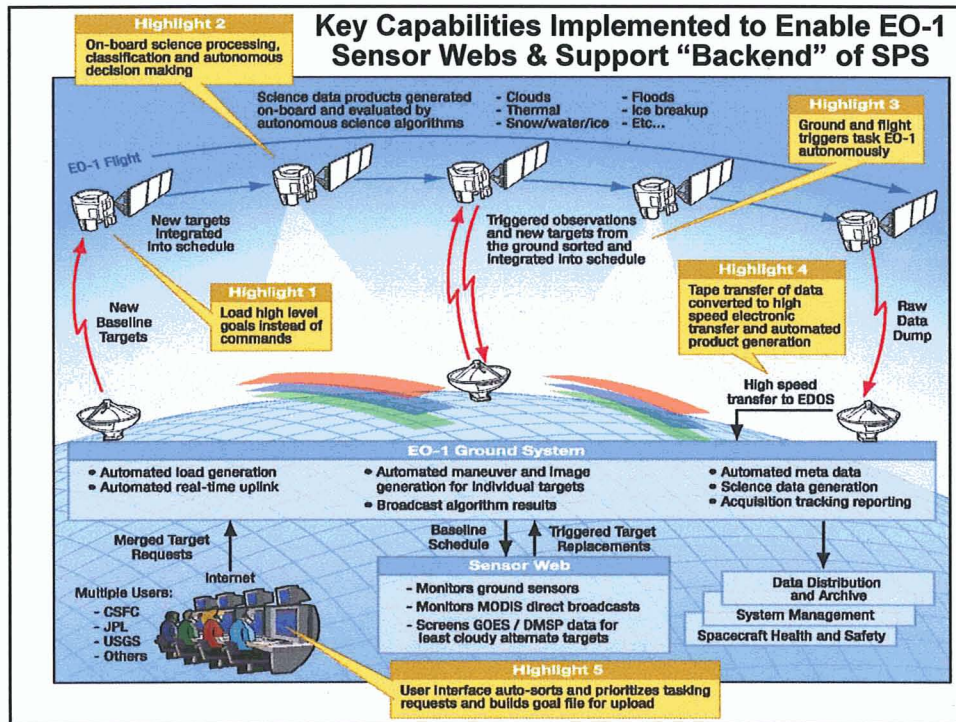


**Advantages of SOA for Space Sensors**

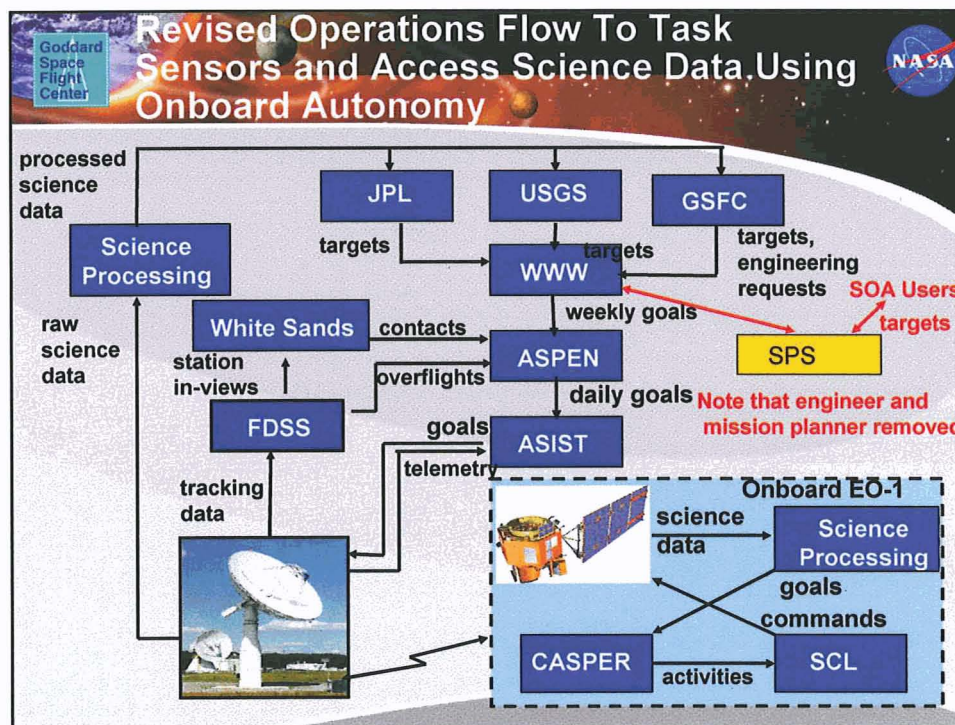
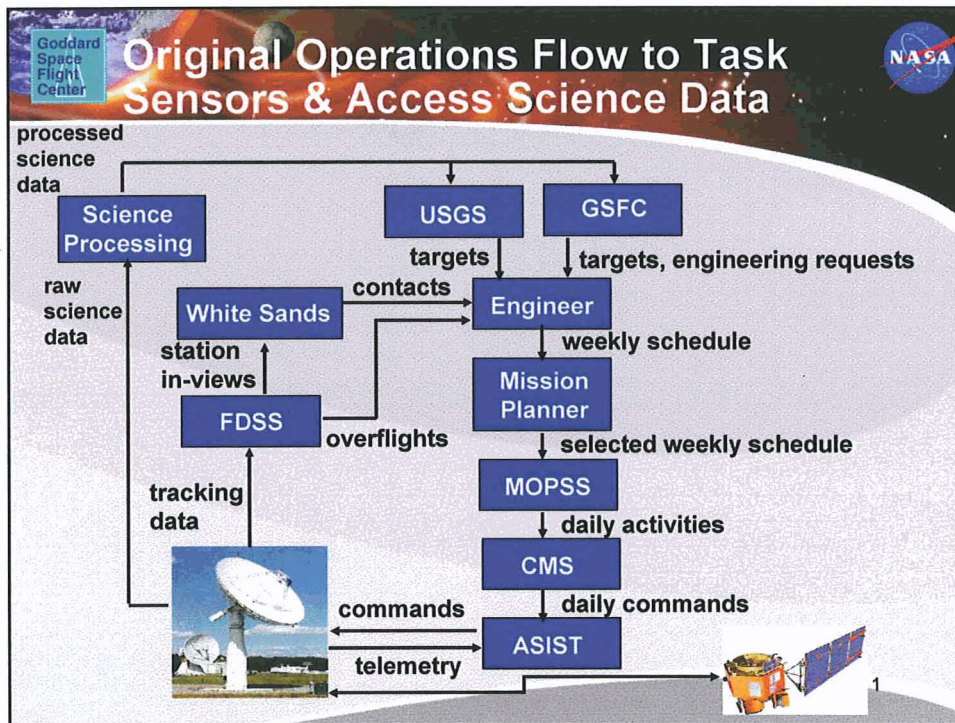
- Networked standardized interface connections, loosely coupled
  - Components connected at run-time
- Enables discovery of services
- Hides details of how service performed (encapsulated implementation)
- Fault tolerant
  - Since connection occurs at run-time, if service not available, a component can find or "discover" an alternative service and if unavailable, can connect to another instance of the service if available
  - Troubleshooting is easier because information is provided at component and services level
- Highly reusable
  - Standardized, networked "plug and play" interfaces
- Scalable
  - Interactions between services and clients independent of location and numbers
- Sustaining engineering for constellation simplified
  - Can initiate new instance of service or alternative service and then disconnect old services

Taken from: Hartman, Hoebel; "Lightweight Service Architectures for Space Missions", SMC-IT 2006, Pasadena, Ca
















## Key Differences





- Scenes and ground contacts are selected automatically based on scene priorities
- World Wide Web interface for requesting and acquiring observations
- High-level scene and contact "goals" are uploaded to the spacecraft instead of detailed command sequences
- Execution sequence can be automatically changed on-board
- Priority observations can be requested and acquired within hours
- Science data is immediately available for analysis on-board compared to days or weeks

13




## Various EO-1 Sensor Web Experiments Conducted







**Volcano Tilt meters, Kilauea, Mauna Loa USGS Hawaii volcano observatory**



**EO-1 responds to triggers and has onboard triggers for snow, water, ice, land, thermal and clouds**




**MODIS (Terra and Aqua) used to detect hot spots for fires, volcanoes, Also used for flood detection MODVOC (Univ. of Hawaii) RapidFire (Univ. of Md.) Dartmouth Flood Observatory**



**GOES/DMSP used for cloud screening near real-time**

Long Island, August 22, 2003




**Ground:**  
 MOPSS: Mission Operations Planning and Scheduling System (GSFC)  
 SGM: Science Goal monitor (GSFC)  
 ASPEN: Planning & scheduling (JPL)  
 EPOS: Earth Phenomena Observing System - Cloud screening (Draper)

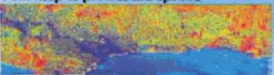
**On-board:**  
 ASE: Autonomous Sciencescraft Experiment (JPL)  
 Livingstone (Ames)  
 - Onboard diagnostic tool

**Communication infrastructure:**  
 Cellular based architecture for spacecraft using phased array antennas (GSFC, GRC, Ga Tech, Univ. of Colorado)


**Fire rehabilitation**



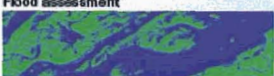
**Fuel map to predict fire spread**




**Volcano eruption detection & assessment**




**Flood assessment**



**Ice breakup change detection**

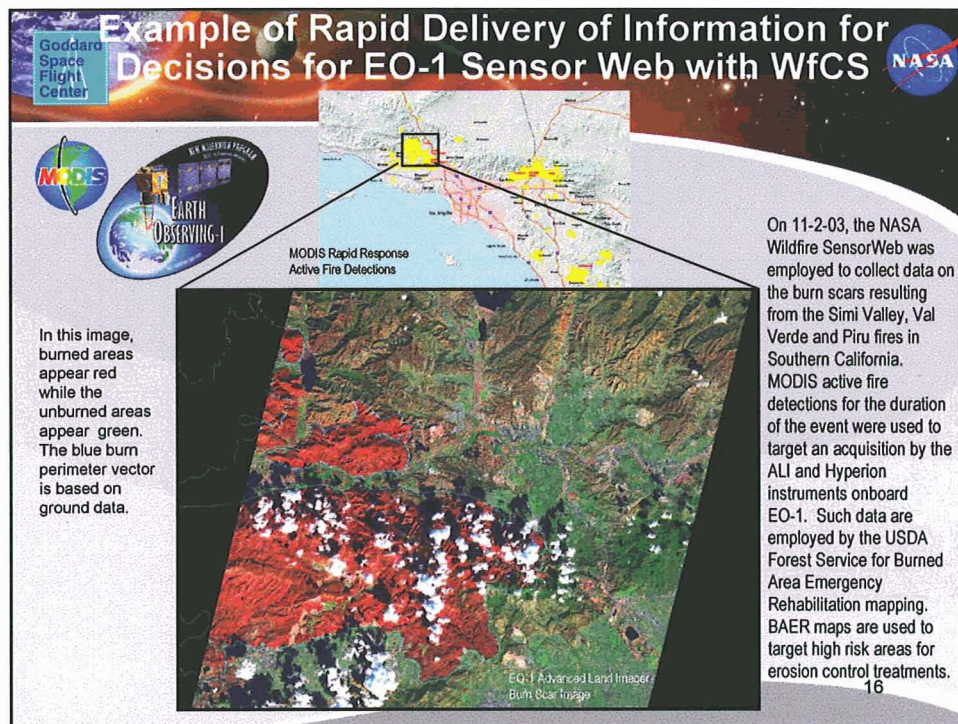


**Cloud screening**

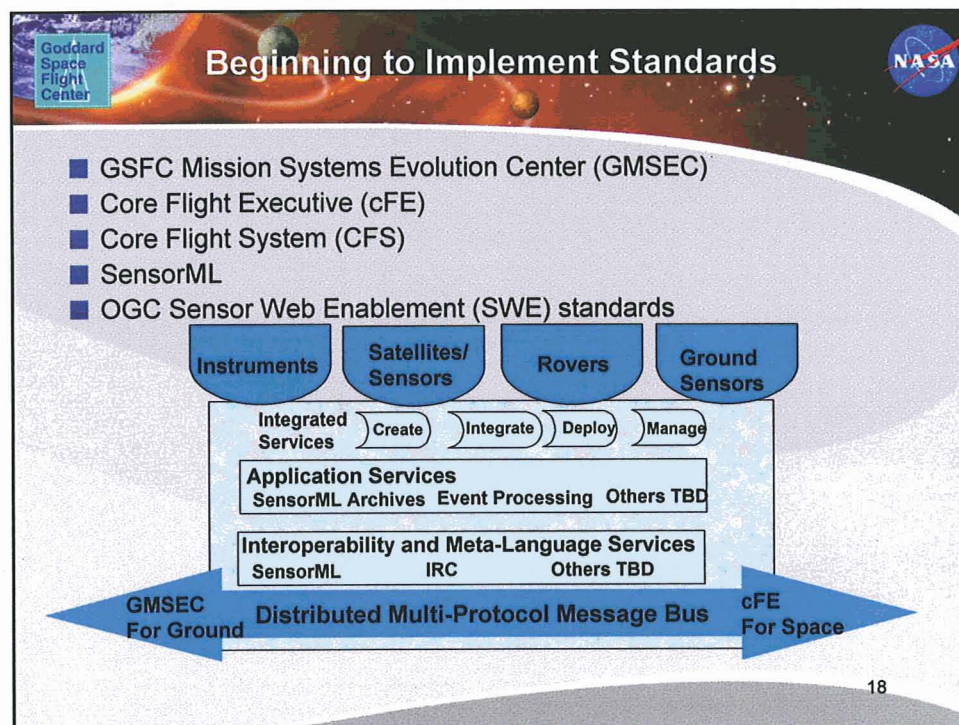
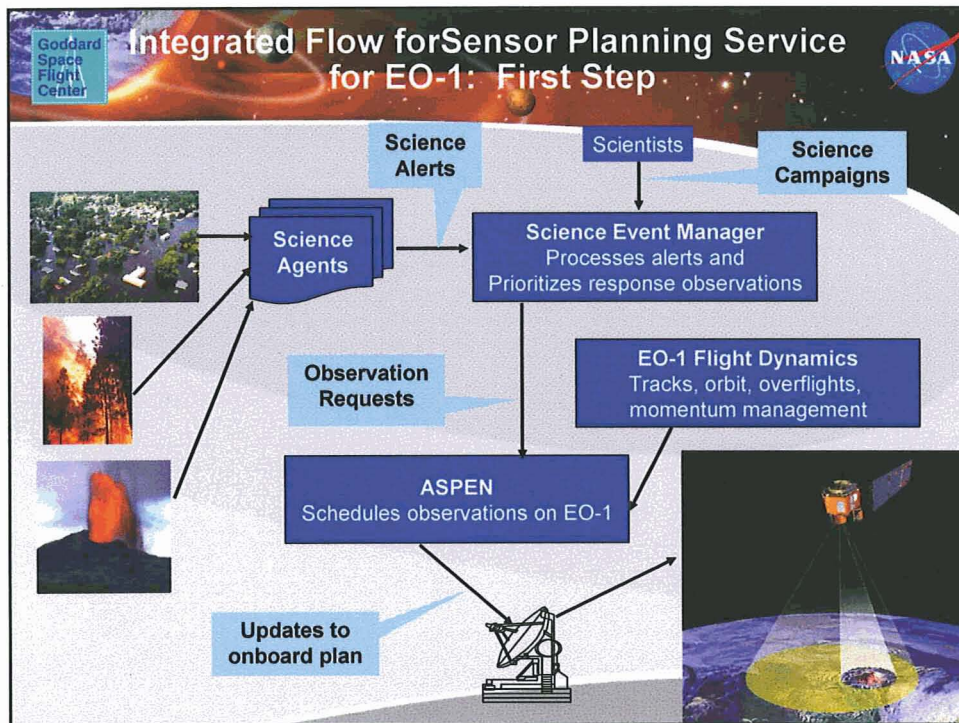


Triggers
Onboard & Ground Tools
Uses

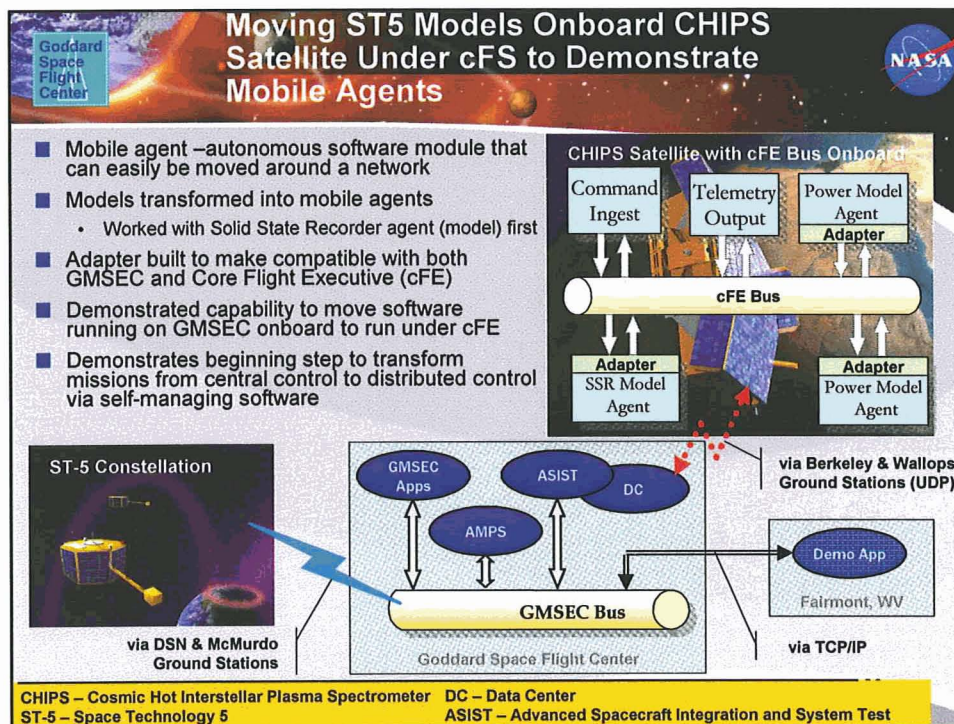
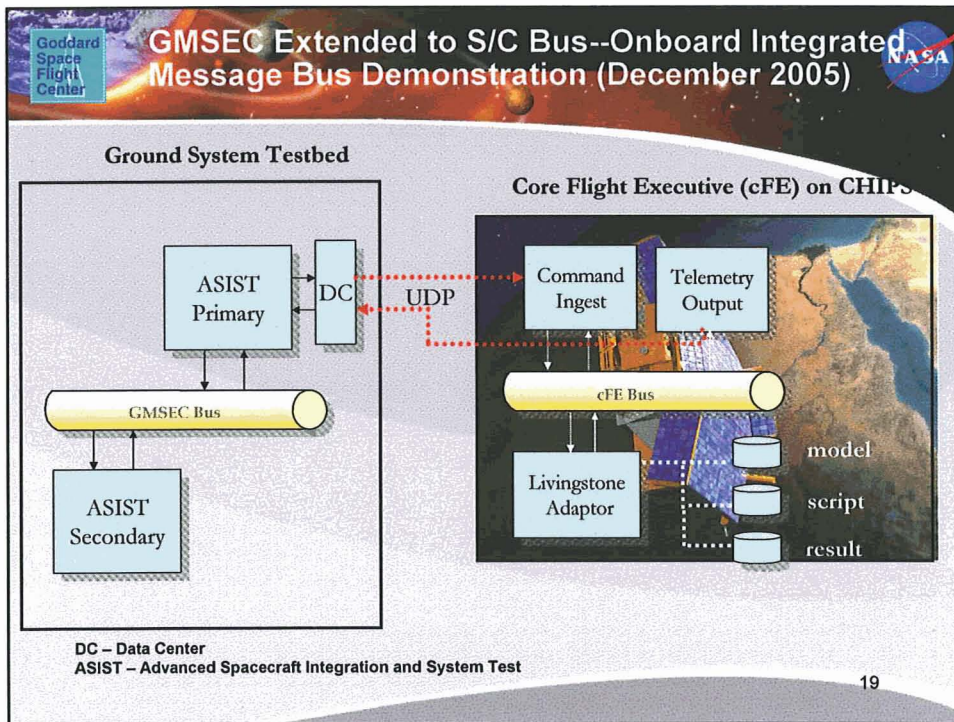














## Extended Efforts



- GMSEC to be used on SDO, GLAST, LRO
- GMSEC providing framework for C3I work in the Constellation Program
  - Will be used for ground and constellation of laboratories
- Two recent follow-on 3 year awards from AIST ESTO call for proposal to extend ST5 efforts
  - *An Inter-operable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS*
    - Key topic – Interoperability and demonstration of service oriented architecture for space missions and sensor webs
    - PI: Dan Mandl - 3 year effort
  - *Using Intelligent Agents to Form a Sensor Web for Autonomous Mission Operations*
    - Key topic distributed mission control
    - Extend effort depicted on slide 16 in which ST-5 components turned into mobile agents for use onboard spacecrafts with GMSEC/CFS
    - PI: Ken Witt/ISR Co-I Dan Mandl/GSFC – 3 year effort

21

## Extended Efforts



- Goddard Institute for Systems, Software and Technology Research (GISSTR) contract effort being applied to extend ST5 effort by Institute of Scientific Research (ISR)
  - Building GMSEC compliance tester for new components
  - Help to synergize other ESTO awards with above mentioned awards
  - Integrate ROME in collaboration with Capitol College into TRMM, GLAST and MMS
- West Virginia Challenge Grant (set-aside) to be applied to develop Sensor Modeling Language (SensorML) schemas for follow-on SOA efforts
  - SensorML schemas will describe sensor capabilities and once put in online registries, will enable discovering of those capabilities on the Internet
- Open Geospatial Consortium (OGC) ongoing testbed effort OGC Web Services 4 (OWS-4) June 2006- December 2006
  - 200 member organization of OGC
  - 40 organization participating in OWS-4
  - Sensor Planning Service (SPS) one of key services being demonstrated with EO-1

22



## Acknowledgements

- Additional info at: [eo1.gsfc.nasa.gov](http://eo1.gsfc.nasa.gov)  
and [ase.jpl.nasa.gov](http://ase.jpl.nasa.gov)
- Other Team Members:
  - GSFC: Jerry Hengemihle, Scott Walling & Bruce Trout (Microtel), Jeff D'Agostino (Hammers), Seth Shulman (Operations Lead, Honeywell), Lawrence Ong (SSAI), Stephen Ungar (EO-1 Scientist), Thomas Brakke
  - JPL: Steve Chien (ASE Principal Investigator), Rob Sherwood (ASE Experiment Mgr), Daniel Tran (Software Lead), Rebecca Castano (Onboard Science Lead), Ashley Davies (Science Lead), Gregg Rabideau, Ben Cichy, Nghia Tang
  - Interface & Control Systems (ICS): Darrell Boyer, Jim Van Gaasbeck
  - Univ. of Maryland: Rob Sohlberg (Wildfire Sensor Web)
  - Univ. of AZ: Victor Baker, Felipe Ip, James Dohm
  - ASU: Ronald Greeley, Thomas Doggett
  - MIT LL: Michael Griffin, Hsiao-hua Burke, Carolyn Upham

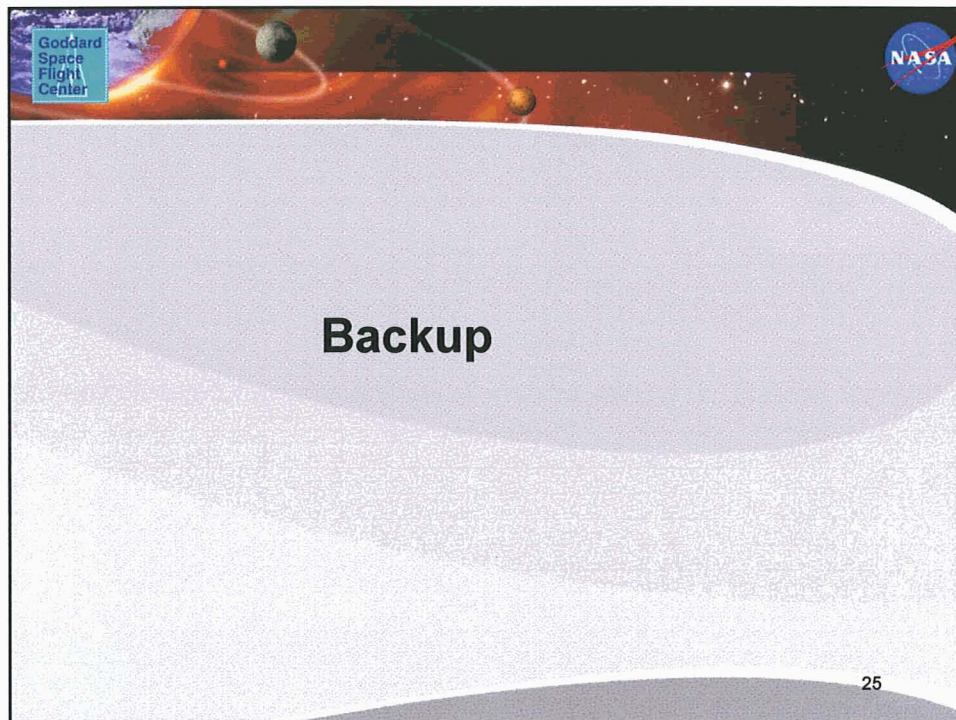
23

## Acronyms

- ASE – Autonomous Spacecraft Experiment
- ASIST – Advanced Spacecraft Integration and System Testing
- ASPEN – Automated Scheduling Planning Environment
- CASPER – Continuous Activity Scheduling Planning Execution and Replanning
- CMS – Command Management Systems
- MOPSS – Mission Operations Planning and Scheduling Systems
- SCL – Spacecraft Command Language

24





Goddard Space Flight Center

NASA

## Underlying "Plug and Play" Message Bus Architecture- Goddard Mission Services Evolution Center (GMSEC)

GMSEC architecture provides a scalable and extensible ground and flight system approach

- Standardized messages formats
- Plug-and-play components
- Publish/Subscribe protocol
- Platform transparency
- ST5 first mission to be totally GMSEC compliant

More info at: <http://gmsec.gsfc.nasa.gov>

PORTALS AND FIREWALLS

FLIGHT DYNAMICS

PLANNING & SCHEDULING

ARCHIVING

TRENDING

TELEMETRY & COMMAND SYSTEM

ADAPTER

GMSEC API

MIDDLEWARE

NETWORK

26

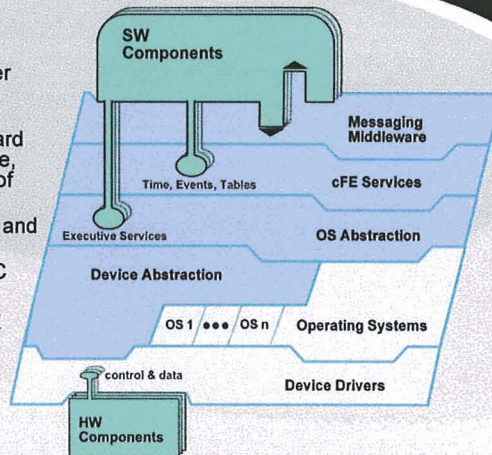


## Core Flight Executive (cFE), an Extension for GMSEC for Flight SW



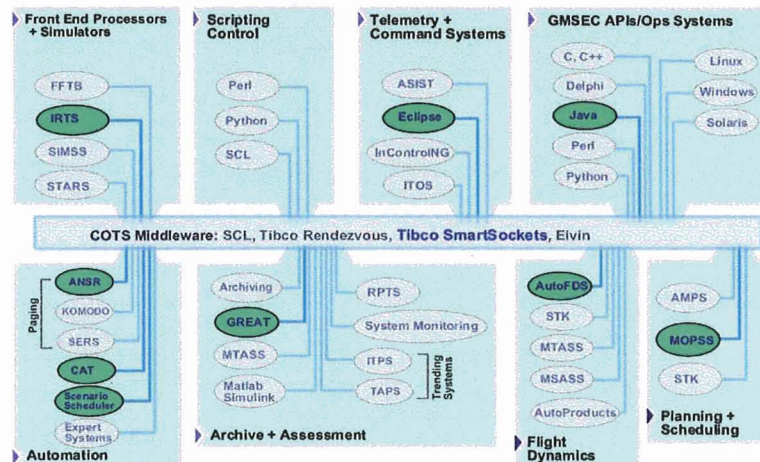
**cFE provides a framework that  
simplifies the development and  
integration of applications**

- Layered Architecture – software of a layer can be changed without affecting the software of other layers
- Components communicate over a standard message-oriented software bus, therefore, eliminating the need to know the details of the lower layers of inter-networking.
- Software components can be developed and reused from mission to mission.
- Developed by Flight SW Branch at GSFC
- To be used on LRO
- More info at: <http://gmsec.gsfc.nasa.gov>



27

## Example of Rapid Mission Configuration Using GMSEC Interoperable Catalog Components



GMSEC approach gives users choices for the components in their system. The TRMM mission rapidly selected key components from the GMSEC catalog.

28